BIDELEK 4.0 – Working on a second "smart" generation

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Abstract—**This project analyses the possible functionalities that could be implemented in the second generation of digital meters for i-DE Redes Electricas Inteligentes S.A.U. These functionalities were proposed in the BIDELEK 4.0 project and would complement the current functionalities. All the proposed functionalities have different requirements that will also be proposed to establish what is needed in the new generation.**

To carry out the evaluation, an analysis was performed using three tools that provide sufficient information to determine which functionalities are viable and should be implemented. These tools are: Cost Benefit Analysis (CBA), SWOT Analysis (Strengths, Weaknesses, Opportunities and Threats) and Key Performance Indicator (KPI) analysis. Each tool provides different information due to the method of analysis employed.

In order to establish whether the functionality is discarded or implemented, the life of the equipment being analysed must also be taken into account, as the decisions to be made have to be valid in the long term. In addition, legislation must be taken into account because it is a key aspect in the changes that can be imposed. The importance of this analysis should be highlighted insofar as it will determine an investment of millions of euros by i-DE.

Keywords* — *Smart Meter, Functionality, CBA Analysis, SWOT, KPIs

I. Introduction

I-DE Redes Electricas Inteligentes is the company of Iberdrola group that carries out the activities of power distribution. This company has several assets among which the electricity meters stand out, since each electrical installation has one at the frontier point between the installation owned by the client and the installation owned by the distribution company.

Nowadays, i-DE has more than 11 million connection points and at each point is located a smart meter that provides power, current and voltage values at the point where the meter is placed [1]. These devices allow the reading of the measures in a continuous mode and enable the reading of the data in a remote way. Therefore, it is an important element of the electrical network. Furthermore, the smart meters are distributed within all the operation area from the distribution company which covers 25 provinces from Spain.

The electricity meters have evolved with technology as has all the devices on the power network. Previously, electromechanical meters were used, which needed a local reading to make the consumption billing. Nowadays, smart meters are in charge of measuring electricity consumption and can send the information registered remotely.

In Spain, the government stablished the deployment of the smart meters in the complementary technical instruction ITC 3860/2007. This order specifies the period of time for the changes of all the meters that the distributors has for the installation, although this period was expanded in the order IET/290/2012.

Smart meters have many functionalities that are installed by the manufacturer according to the requirements of each distributor, but some minimum functionalities are established in the RD 1110/2007, the Royal Decree-Law that states the regulation for the measurement points of the Spanish electrical system. Some of the detailed functionalities in the Royal Decree-Law are the measurement of active and reactive energy, the supply of measurement data remotely and reliably, the possibility of limiting the power demand or the hourly discrimination capacity of the consumption made [2].

On the other hand, the energy transition and technological evolution is manifested in a development of the electrical network. This requires the installation of new element and the adaptation of existing elements in order to implement the necessary capacities to carry out this development. In the case of smart meters, the distributors have identified new functionalities that are necessary in order to know and control the network in a proper condition and let the installation of some technologies. Therefore, these meters need an evolution where the necessary elements are included in order to do the required tasks and the corresponding software must be developed.

It must be taken into account that the smart meters are installed in each user and these devices are property of the distribution company, which afford the investment cost. The method to recover the investment is by charging users for the rental of the measurement equipment. The rental price is regulated and specified in the Royal Decree-Law 1634/2006, which includes the installation and verification costs for the meters. For example, a residential consumer with a single-phase smart meter must pay 0.81 euros per month and 1.36 euros per month for a three-phase smart meter according to [3]. These regulated prices do not allow the installation of all the functionalities that the distributor can design, but they must analyse which functionalities are economically and technologically feasible. Furthermore, smart meters have a useful life and when it comes to the end, they must be replaced by a new generation which is the best time for the implementation of functionalities.

The main goal of this project is to devise a solution to the implementation of the functionalities in the new generation of smart meters of i-DE, performing an analysis of the different functionalities that will allow to know which of them is more necessary based on the benefits provided to the DSO (Distribution System Operator). On the other hand, the analysis will also take into account the economic criteria to establish a relationship between the benefits and the associated cost, since all implemented functionality must be economically feasible.

II. Desgined Methodology

In this section of the document, the methodology that is going to be used in the process of analysis will be presented. The methodology will evaluate all the functionalities that are proposed. It will be composed of various analysis tools that will be explained below. Furthermore, it will be presented how the analysis will be done to facilitate its comprehension and replicability in future projects.

In this case, the evolution of the meters through the implementation of new features will be analysed. But the functionalities must be developed by the manufacturers and tested by a laboratory. Therefore, the participation of this part should be highlighted and taken into account.

The analysis is carried out into 32 functionalities that are proposed in BIDELEK 4.0 [4]. The functionalities consider the proposals from all the stakeholders of the meter.

A. *SWOT Analysis*

The SWOT (Strengths, Weaknesses, Opportunities and Threats) Matrix is a quantitative and qualitive analysis which studies both internal and external aspects. Among the external aspects, there are threats and opportunities. While the internal aspects analysed are the weaknesses and strengths. Therefore, a joint evaluation of all the influential aspects in each functionality is carried out.

The methodology employed for this tool will be asking some questions for all the functionalities that will be the same and some specific questions for each one. The general question will be stated in the following paragraphs, they also present a common point that will be helpful in the comparison process. The questions will be different for each aspect of the SWOT.

The opportunities are positive factors that can give an advantage to each functionality. In addition, they must be exploitable by the company. To identify the opportunities, it can be answered questions such as:

- What are the trends that the market is showing which you can complement?
- What thoughts does society have about it?
- What ecological and technological factors influence and if there is capacity to do so?
- Is it an innovation compared to the existing functionalities?

In the case of threats, it has to be taken into account that they may endanger the implementation of the functionality or to a lesser extent affect the installation due to an increase in size or other reasons. If it is identified a threat sufficiently in advance, it can be avoided or turned into an opportunity. To identify threats, it can be answered questions such as:

- What are the barriers to the development?
- Are there problems to recover the cost?
- Is the functionality affected by regulations or by current technology?

The strengths are all the capacities and resources that the functionality has to benefit from the opportunities and to be able to build advantages. In order to identify them, it can be answered questions such as:

- What new information does the functionality provide?
- What contributions do they make?
- What benefits does the functionality bring to each of the stakeholders?
- What are the benefits in terms of quality?

The weaknesses are the points that the company lacks, those in which it can improve. To identify the weaknesses from the company, it is possible to answer questions such as:

- What do our clients perceive as weaknesses of the functionality?
- How can they be improved?
- Can it be solved through another functionality?
- Does this functionality affect the operation of other functionalities?

B. *CBA Analysis*

The Cost Benefit Analysis (CBA) is a tool that provides information of the monetary appraisal but it also includes the society perspective. It analyses the cost produced for the implementation of a technology or the use of an asset and the benefits provided by them in economic terms and quantify the benefit of the society. Therefore, it is a very useful tool to check the viability of the implementation of a strategy, idea, technology among other aspects.

There are two main approaches in order to carry out the analysis, from the policy maker or from the technology adopter. In the case of the policy maker, the analysis is centered in the benefits for the society and the cost allocation is not crucial because it will guide the future regulation. Meanwhile, the technology adopter approach will stablish the basis for future investments. For this analysis, the approach that is going to be used is the technology adopter. The distribution system operator (i-DE) will be the technology adopter.

This process will be helpful in order to find all the factors that are affected by each functionality. It should be highlighted that all the functionalities will be analysed in the same process for the asset and benefit identification, although the computation of financial returns will be performed on each functionality independently.

The CBA will be done in 7 steps, which characterize the project, estimate the benefits and compare these benefits with the cost. Figure 1 states the different steps for the CBA analysis using the guidelines to conduct an CBA. These guidelines were done by the Joint Research Centre of the European Commission based on the EPRI (Electric Power Research Institute) methodology [5].

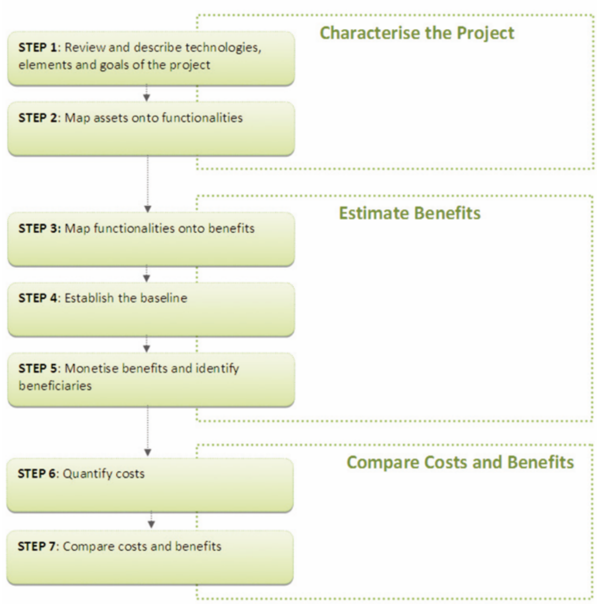

Fig. 1. Steps performed in the Cost Benefit Analysis [5].

These steps will be adapted to the project because it is being analysed the functionalities that may be installed into the meter. So, the characterisation of the Project will be adapted because it will not analyse a technology or a device that can be installed. The project will review the different functionalities then it will present the asset that are necessary to install in the meter for its implementation.

When the functionalities are explained and the assets are stablished, it will be performed the benefit estimation. The estimation of benefit will be based in the benefit associated to each functionality and the monetary benefits for i-DE, although the benefits that will perceive the clients of the distribution company will be presented. The benefits for the manufacturer will be presented because they are proportional to the costs of functionalities implemented.

Among the benefits there are two types, those that are punctual and those that are cyclical. Cyclical benefits will bring profit to the company during the life of the meters, meanwhile the punctual benefit provide the earnings in the year of its installation alone. The analysis will take into account the period from the first installation till the end-of-life from a meter which will be installed in the last deployment.

The installation period that is going to be analysed is ten years and it will begin in 2023. The meter replacement plan is stated in Table I. The useful life considered for each meter is 15 years, as it is stated in the ITC 155/2020. It should be noted that the useful life of the meters installed in 2016 and 2017 are extended 5 years, although for the analysis is considered that all the meters will have the same useful life. Therefore, the end of the project that is going to be analysed will be 2047 which implies the installation period plus the useful life of the meter.

Furthermore, the new clients that will be connected to the distribution network of i-DE will be considered. New clients are represented in the values of 2023 and 2024, which correspond to an increase of a one percent. This increase is stablished by the business as usual.

TABLE I. SMART METERS INSTALLED PER YEAR IN THE METER REPLACEMENT PLAN

Year	**Installed meters**	**Total meters installed**
2023	110,000	110,000
2024	110,000	220,000
2025	122,470	342,470
2026	247,641	590,111
2027	809,159	1,399,270
2028	1,150,255	2,549,525
2029	2,161,249	4,710,774
2030	2,486,926	7,197,700
2031	2,483,457	9,681,157
2032	1,743,483	11,424,640

In the economic analysis of the functionalities there will be two cases. The functionalities that can be economically analysed and the functionalities that have not a direct financial return. The functionalities which does not provide a profit does not mean that are directly discarded because they could be imposed by the regulation or the benefit in some different tasks provides its validation.

In the case of the functionalities that are analysed it will be computed the Internal Rate of Return (IRR) and the Net Present Value (NPV). The NPV is an investment criterion that consists of updating the cashflows of an investment in order to know how much will be earn or lost with that investment. The formula for the calculous of NPV is stated in (1), on which I0 stablish the initial investment, Ct are the future cashflows and r is the rate of discount.

$$PV = -I_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} \quad (1)$$

The IRR is the return that an investment offers. So, it is the percentage of profit or loss that an investment will have for the amounts that have not been withdrawn from the project. It is related to the NPV because it is calculated by equalising to zero the NPV and the IRR is obtained. The formula of the IRR is specified in (2). When the value obtained in the IRR is higher than the value of the discount rate, the earnings obtained will be higher. So, the sooner the functionality is installed, the benefits will increase.

$$0 = -I_0 + \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t} \quad (2)$$

For the calculous of these parameters, it should be considered the values of the necessary data. The prices will be constant because they are imposed by the government. Concretely, the prices are stablished on BOE nº 312 from 28th December 2019, which specifies the regulation that will be used for the following years. The cost that are going to be used in the analysis are the cost specified in the tariff 2.0 without time discrimination. The discount rate is the interest rate employed in the project in order to determine the present value of a future cashflow. The value of the discount rate is aligned with EU wide benchmark set by the European Commission. All the data is specified in the Table II.

TABLE II. COEFFICIENTS EMPLOYED IN THE CBA ANALYSIS

Coefficient	**Value**
Regulated cost of energy consumed (€/kWh)	0.044027
Regulated cost of contracted power (€/kW)	38.043426
Percentage for transmission and distribution (%)	40.33
Percentage for distribution (%)	≈ 76.00
Discount rate (%)	4.00

C. KPI Analysis

Finally, a KPIs (Key Performance Indicators) analysis will be carried out to evaluate the different functionalities from an objective point of view. With this analysis, the different characteristics that the functionalities may have will be weighted. Therefore, useful information will be provided to compare the different functionalities in a qualitative way. This analysis will be based on the knowledge obtained in the two previous analyses, since it requires a deep knowledge of the different functionalities.

The evaluation will be performed using five KPIs that will focus on the main features of the functionalities. In order to evaluate the contribution of the functionalities, different contributions will be presented with respect to the KPI. These KPI and the features are the following:

- KPI1: Improvement of security and quality of the communications

The feature that will be evaluated are the Reduction of risk due to non-allowed access into the meter. This feature aims to identify functionalities that improve the security of meters and their information. The second feature will be the Implementation of new communication technologies that allow to improve the communications between the HES-MDC and the meters. The third feature will be the introduction of a change into the communication configurations to have a more reliable communication system. Finally, if it will evaluate if the data transmission with the functionality will be made of a more efficient way.

- KPI2: New and enhanced client services

This KPI seeks the improvement or the creation of new services that the distribution company provides. For its evaluation, the following features are considered New client services that improve the management of energy consumption, new information supply that can be used by the clients or the distributor, reduction of outages or the number of instantaneous disconnections and the reduction of energy losses.

- KPI3: Enhanced power network operation

This KPI aims to verify the contribution that the functionalities have in the operation of the distribution network. Evaluating the following features the implementation of new mechanisms in order to support the balance between the demand and the generation, the supply of new information that can be used for the automation of the system, the reduction of work performed by operators or works on field and the improvement of the security from the supply and the facilities.

- KPI4: Effective support for power network evolution

Effective support for power network evolution KPI aims to obtain an alignment with the energy transition and the achievement of an environmentally friendly business. Therefore, it is tested whether the functionalities promote a system operation that aims to achieve Sustainable Development Goals (SDGs) or reduces emissions both in the form of waste by the distribution company (as the removal of stickers on the meter) or gases produced by the generators. For gas reduction, the introduction of DERs (Distributed Energy Resources) is evaluated.

- KPI5: Economic benefits

This KPI is the simplest and is divided into the provision of benefit to the customer and the distribution company in financial terms.

All the characteristics from the KPI will have a weighting to give more weight to the most important characteristics of the KPI. To carry out the analysis, some points will be established for each characteristic that will be multiplied with the weighting in order to have the final value of each functionality. When all the functionalities are computed, they can be compared.

III. SPECIFIC CASE

The functionality that is going to be analysis to present the methodology into a specific case is R10 – Smart three-phase injection. This functionality is intended to make three-phase meters capable of sending spontaneous events through all phases. The injection is smart because the meter will decide on which phase the transmission will be performed. It will allow sending information if one or two of the phases fails, since currently single-phase meters cannot send this type of event if the failed phase is on which they are connected.

For this purpose, a PRIME transmitter module will be installed that will have the capacity to exchange the injection between the three phases. The choice of the phase to carry out the transmission of events will be made by the meter and the chosen phase for transmitting will be the one with the best communication capabilities. So, the interruptions and the noises on the communications will be avoided.

In the following sections, the

A. SWOT Analysis

Strengths:

- The communication will be performed in the cases when a phase or two is/are lost.
- The meter will transmit in the cable that has lower interferences or noises.
- The distributor will have a communication the majority of the time.

- The client will see this functionality as an increase of the quality of supply.

Weaknesses:

- It requires a new interchangeable plc module.
- It will not offer a solution for the single-phase meters.
- There will not be many clients that has the benefit of this functionality, around an 8 % of residential customers and 40% of secondary substation do not have a three-phase meter.

Opportunities:

- The increase of manoeuvres, the distributed generation and the demand response require a reliable communication in order to transmit all the events that happens in the grid.
- A device could be installed into the secondary substation if there is not a three-phase meter installed.

Threats:

- The reduction of the failures can affect in the financial return of the functionality for domestic three phase customers with a fix meter rental price.
- The modules could not feet into the meter.

B. CBA Analysis

The functionality of the intelligent three-phase injection allows to know if any of the phases has been lost, because the single-phase meters connected to this phase will not be able to transmit the event. But with this functionality, the three-phase meter will send the event through the phase which has better communication. Therefore, it is possible to reduce the SAIDI (System Average Interruption Duration Index) which will bring a benefit to the distribution company.

The cost is composed of a software development cost and the cost derived from the new communication module that will be installed in the three-phase meters. It should be taken into account that the three-phase meters connected to the distribution network are eight percent of the total meters. This communication module is new and its cost is not known precisely, so an estimation of two costs has been provided by the manufacturers. In this analysis the most expensive cost will be presented because if it is viable, a lower cost of the module will be more feasible.

A reduction of the SAIDI can bring different benefits according to the area where the secondary substation is located, distinguishing between urban, semi-urban, concentrated rural and dispersed rural areas. Their values will be harmonised using an average to obtain the common value for all areas. This value is established in euros per reduced kVAh and the reduction will be carried out in one phase of a secondary substation that has three-phase meters. Only 60 percent of the secondary substations have meters of this type.

The average contracted power of a secondary substation is 606 kW in i-DE. The active power has been changed to apparent power using of a power factor of 0.85 because if it is higher it will be more beneficial. Furthermore, it is estimated that failures will be detected in 10 percent of all secondary substations.

Finally, it has to be considered the time that this functionality would reduce. In this case the time reduction is considered to be one hour, as this would be the time required by the clients to contact the customer service and verify this fault.

Performing all the calculous for the cashflows, the Figure 2 is obtained and the IRR is 22 percent. So, the implementation of the functionality is justified.

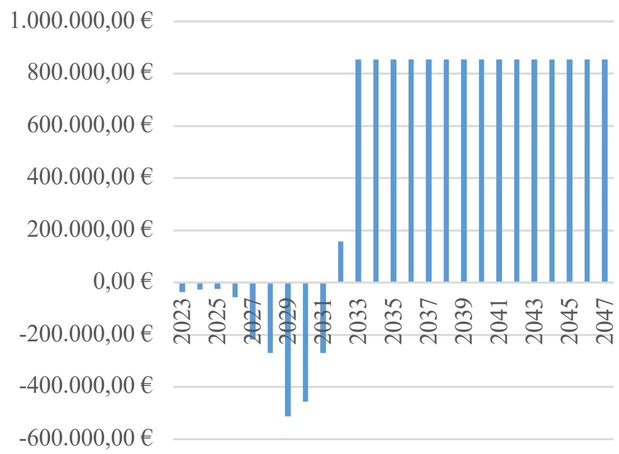

Fig. 2. Functionality R10 – Smart three-phase injection cashflows.

C. KPI Analysis

Within the evaluation of KPIs it is one of the functionalities that stands out due to its different contributions both in the introduction of new services or in the economic contribution. But it also facilitates the operation of the system due to the deep knowledge of the network in advance of the current situation.

In the case of customers, they perceive a new service which is the communication of the loss of their supply. Currently, if a phase is lost, the customer must communicate that the supply is not available and with this functionality they would not have to contact the customer service department because the fault would already be registered.

In terms of economic contribution, the greatest contribution is linked to the quality of supply perceived by the distributor because it receives a contribution for reducing the SAIDI. For clients, damages due to power outages would also be eliminated, such as damage to refrigerated or frozen products.

The Figure 3 shows the contribution in each of the KPIs. This data allows a direct and visual comparison with other functionalities that allow the improvement of communications and send a similar event to the network operator. But this functionality stands out from the others because of its characteristics. Moreover, the functionality does not have to be implemented in all the meters but it will only be installed in the 8 percent of the meters installed because they are the three-phase meters.

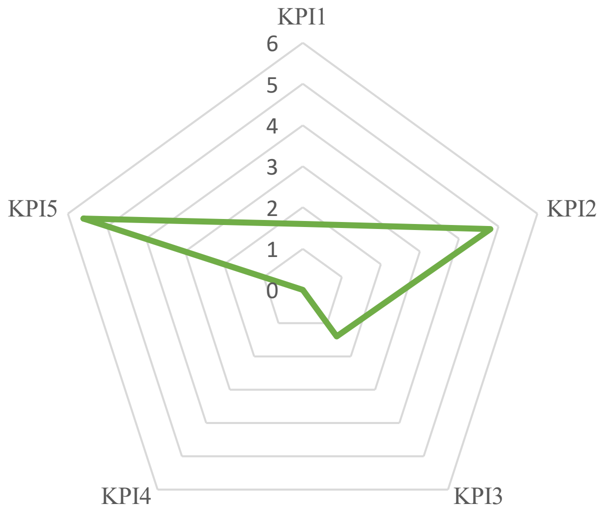

Fig. 3. R10 – Smart three-phase injection evaluation on KPIs.

IV. Final Results

This section of the document will present a summary of the results in the Table III, obtained from the different analyses that have been carried out on the different functionalities. The R19 – Active demand management and R5 – Point-to-Point remote management meter functionalities should be highlighted due to the conditioning factors involved.

The implementation of the R19 – Active demand management functionality, although it is not defined as feasible due to the associated benefits, present a software implementation cost very small and its contribution to the client is high. Therefore, it is a requirement that should be defined by the distribution.

The implementation R5 – Point-to-Point remote management meter should be implemented because the transmission of data is secured. So, a change in the communication configuration will be efficient for the network. But this functionality must have a special casuistry that must be conditioned. The meters should be found in isolation, since the cost of their hardware implementation is higher than if a filter were installed. A filter would mean the improvement of the communication of the meters connected in the same phase while the modem would require one modem per meter. Therefore, the cost of software implementation should be assumed and installed in very specific cases.

TABLE III. Summary of Functionalities Implementation for New Meters

Functionality	**Implementation**
R1 - Physical measurement of neutral current	X
R2 - Temporary overvoltage protection	X
R3 - Islanding detection	X
R4 - In Home Display. Information for the user	X
R5 - Point-to-point remote manage of the meter	≈
R7 - Phase detection in PRIME 1.3	X
R8 - Meters with PRIME 1.4 compatibility	✓
R9 - Meter reclosing	✓
R10 - Smart Three-Phase Injection	✓
R11 - Load curve with shorter integration periods	X
R12 - Power load curve of each phase	✓
R15 - IEC 61000 Standard	X
R16 - V-I profile registration	X
R17 - Instant Values and Connectivity	X
R18 - Rotation sequence in three-phase meter	✓
R19 - Active demand management	≈
R20 - Volt-free contact	✓
R21 - Use of supercap for battery replacement	✓
R22 - New report S05 / S05B / S04 /S27	✓
R23 - Led for verification of impulses	✓
R24 - STAR+ Cybersecurity. Narrow band.	✓
R25 - Trigger power information	X
R26 - Reboot Modem PRIME	✓
R27 - Excess Calculation	✓
R28 - Events	✓
R29 - DLMS Efficiency	✓
R30 - Regulatory adaptations	✓
R31 - RMS values	✓
R32 - Instantaneous Values Profile	✓

V. Conclusions

The electric meter is a fundamental equipment in the monitoring, energy billing and diverse tasks that must be carried out in the electric distribution network. Therefore, it must be updated and implemented new functionalities that allow the evolution of the network and at the same time facilitate the tasks of the operators. Furthermore, it should be performed carefully due to the high investments that the implementation of the functionalities incur.

In order to make an objective decision on which functionalities should be installed and which should be discarded, deep reflection should be carried out, avoiding the inclusion of personal prejudices. For this reason, the service life of the equipment and its economic and technical implications must be taken into account, as well as the contributions they have in all stakeholders. It can be stated that the benefit for one of the stakeholders of the meter is not enough to justify the installation of a functionality. It is necessary that the functionality contributes to all stakeholders, although it is easier to bring benefits to manufacturers or laboratories because for them the greater number of features, the greater their benefit.

An effective method of comparing features is to use KPIs to identify the key characteristics to be compared. However, in order to evaluate the contribution of KPIs, a thorough knowledge of the functionality is required. This can be done by a previous SWOT analysis or some method of analysis of all the contributions and errors of the functionalities. KPIs provide information and highlight the aspects of each functionality that can be improved.

Legislation is a key aspect in the functionalities that must be installed in the meters, since as it has been established throughout the project the regulation may impose or rule out the installation of a functionality. But the installation of meters is not done every day, so the functionalities also have to be aligned with the regulation and the possible changes they may have or the technology to be promoted. Once the meters are installed it would be much more expensive to implement any hardware device to allow the installation of a new resource.

The data that is transmitted by the meters is increasing due to the new resources or devices requires. For this reason, continuous improvement in meter communications must be made because technology continues to advance and communication capability can be enhanced. In addition, it is necessary not only to transmit more data but also more reliably. For this, modifications can be made in the configuration of those meters that do not transmit by the current configuration. But it must be emphasized that the current configuration, which use PLC technology, is very reliable. Due to this reason, updates should be carried out in the current protocols for its update.

To continue with this project, small pilots could be carried out to evaluate if the contributions of the different functionalities that require a hardware device are real because these functionalities are the most expensive in cost terms. In the laboratory, the functionalities can perform an efficient work but the different features of the network with the influence of external factors could influence the performance functionalities. Therefore, a future work would be to carry out the analysis of the evolution of the functionalities in the pilots to certify their implementation. The meters should be installed in small groups but the location of the groups should be different in order to certify the proper operation having different conditions.

Another work that can be continued is the development of algorithms to perform the automation of equipment with the new data provided. Various functions will obtain information that was not previously recorded and this information must be treated. Therefore, it is necessary to develop algorithms that treat the information. In the case of the i-Trafo, it requires an algorithm that checks the information and send an order to the transformer in order to change its condition. i-Trafo is a transformer installed in a secondary substation and has an OLTC that allows optimizing the voltage in the secondary of the transformer. So, the algorithm will send an order an order to optimize the tap on which the transformer is working.

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